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Quantitative Approach to Incorporating Stakeholder Values into Total Maximum Daily Loads: Dominguez Channel Case Study

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Quantitative Approach to Incorporating Stakeholder Values into Total Maximum Daily Loads: Dominquez Channel Case Study

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ABSTRACT

The federal Clean Water Act (CWA) Section 303(d)(1)(A) requires each state to conduct a biennial assessment of its waters, and identify those waters that are not achieving water quality standards. The result of this assessment is called the 303(d) list. The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and to develop and implement Total Maximum Daily Loads (TMDLs) for these waters. Over 30,000 segments of waterways have been listed as impaired by the Environmental Protection Agency (EPA). The EPA has requested local communities to submit plans to reduce discharges by specified dates or have them developed by the EPA. An investigation of this process found that plans to reduce discharges were being developed based on a wide range of site investigation methods. The Department of Energy requested Lawrence Livermore National Laboratory to develop appropriate tools to assist in improving the TMDL process. The EPA has shown support and encouragement of this effort.

Our investigation found that given the resources available to the interested and responsible parties, developing a quantitative stakeholder input process could improve the acceptability of TMDL plans. The first model that we have developed is a stakeholder allocation model (SAM). The SAM uses multi-attribute utility theory to quantitatively structure the preferences of the major stakeholder groups, and develop both individual stakeholder group utility functions and an overall stakeholder utility function for a watershed. The test site we selected was the Dominquez Channel watershed in Los Angeles, California. The major stakeholder groups interviewed were (1) non- profit organizations, (2) industry, (3) government agencies and (4) the city government. The decision-maker that will recommend a final TMDL plan is the Los Angeles Regional Water Quality Control Board (LARWQCB). The preliminary results have shown that stakeholders can have different preferences, especially in the areas of scheduling and cost of the implementation plan. The SAM model gives the decision maker the ability to see how the different TMDL plans rank in order of preference from the perspective of each stakeholder and also to evaluate tradeoffs in selecting a plan that maximizes overall utility. We have included a preliminary example comparing two TMDL plans based on the decision makers' preferences but, final decisions are not disclosed in this paper due to ongoing negotiations by the stakeholders.

KEYWORDS

Total Maximum Daily Loads, Stakeholder Values, Multi-Attribute Utility Theory.

1: INTRODUCTION

The court mandate requiring the development of Total Maximum Daily Loads (TMDLs) has required the federal Environmental Protection Agency (EPA), local regulatory bodies, and stakeholders to make decisions on complex problems with limited resources. The 30,000-plus waterways that are required to have TMDLs developed receive contaminant loadings from point, non-point, and background sources. Atmospheric deposition, surface and subsurface waters, and legacy sources can contribute to the contaminant loadings in a watershed. A lack of information from any one of these potential sources can cause an increased burden on the known sources to reduce discharges from the known sources.

The receiving waters of the combined source dischargers are regulated by federal, state, and local government agencies. These agencies are required to limit discharges to a level considered safe for public use. The public is considered a stakeholder in the TMDL process and therefore has input into the process. This process brings stakeholders with multiple objectives together. A decision-maker, in this case the California Water Quality Control Plan, Los Angeles Region, (also known as the Los Angeles Regional Water Quality Control Board, or LARQWCB) must weigh the various objectives of each stakeholder when determining the final implementation plan.

2: BACKGROUND INFORMATION

2.1 Regulatory Background

The State of California's principal water quality law is the Porter-Cologne Water Quality Act (Porter Cologne). Porter Cologne is implemented in the Los Angeles region by the California Water Quality Control Plan, Los Angeles Region (Basin Plan). The Basin Plan sets water quality standards for the Los Angeles region, which include beneficial uses for surface and ground water with the numeric and narrative objectives necessary to support those uses, and the state's antidegradation policy. The Basin Plan also describes implementation programs to protect all waters in the region. The Basin Plan will serve as the State Water Quality Control Plan for Dominquez Channel.

These plans are required by and in compliance with the federal Clean Water Act (CWA).

Section 303(d)(1)(A) of the CWA requires each state to conduct a biennial assessment of its waters, and identify those waters that are not meeting water quality standards. The result of this assessment is called the 303(d) list. The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters, and to develop and implement TMDLs for these waters.

A TMDL specifies the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and allocates the pollutant loadings to point and non-point sources. The elements of a TMDL are described in 40 CFR 130.2 and 130.7, and Section 303(d) of the CWA, as well as in U.S. EPA guidance (U.S. EPA, 1991). A TMDL is defined as the "sum of the individual waste load allocations for point sources and load allocations for non-point sources and natural background" (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loads (the loading capacity) is not exceeded. TMDLs must take into account seasonal variations and include a margin of safety to address uncertainty in the analysis (40 CFR 130.7(c)(1)). Finally, states must develop water quality management plans to implement the TMDLs (40 CFR 130.6).

The U.S. EPA has oversight authority for the 303(d) program, and is required to review and either approve or disapprove the state's 303(d) list and each TMDL developed by the state. If the state fails to develop a TMDL in a timely manner, or if the EPA disapproves a TMDL submitted by a state, the EPA is required to establish a TMDL for that water body (40 CFR 130.7(d)(2)).

In the Los Angeles region, as part of its 1996 and 1998 regional water quality assessments, the Regional Board identified over 700 local water body-pollutant combinations where TMDLs would be required (LARWQCB, 1996, 1998). A 13-year schedule for development of TMDLs in the Los Angeles region was established in a consent decree approved on March 22, 1999 (Heal the Bay Inc., et al. v. Browner, et al., C 98-4825 SBA).

As required by the CWA and Porter-Cologne, Basin Plans include beneficial uses of waters, water quality objectives to protect those uses, an antidegradation policy (water quality standards), and other policies necessary to implement water quality standards. TMDL implementation plans are incorporated into the Basin Plan.

2.2 Land Use

The Dominguez watershed is predominantly urban-industrial (96%) and approximately 62% of the land surface is impervious, with drainage occurring primarily through the storm drain system to the Dominguez Channel, and through the main ship channel to the Los Angeles Harbor (DWAC, 2003).

For decades, the area called "consolidated slip" at the mouth of the channel has acted as a sink for contaminated sediments. The Dominguez watershed, located upstream of the slip, is highly urbanized and discharges into the port through consolidated slip. Since the early 1900s, millions of gallons of point-source industrial wastewater have been discharged into the Dominguez Channel, contributing to the contaminant loading. The channel is also the main carrier for municipal and industrial non-point storm water runoff for a large area of southern Los Angeles County.

2.3 Climate

The area has a Mediterranean climate, with warm summers, mild winters, and rain occurring primarily November through April. The annual rainfall for a typical dry year and wet year are 5.53 inches and 20.67 inches, respectively.

2.4 Dominquez Channel

In the Dominquez Channel, the California Regional Water Quality Control Board, Los Angeles Region, must propose a TMDL that, after several approval steps, must ultimately be approved by the EPA. Like many TMDL plans, a local agency is tasked with: determining the sources of discharges; proposing a timetable to reduce discharges to legal limits; and periodically monitoring the water body to ensure that the implementation agreement has been instituted by the stakeholders and that the implementation plan is actually meeting the goals of reducing specific types of discharges to the targets specified in the TMDL plan. If the plan is not meeting the original goals, a revised plan may be implemented at a future date. In Figure 1, a satellite image of the Dominquez Channel shows a predominantly urban and industrialized part of Los Angeles and Long Beach. The ports of Los Angeles and Long Beach border each other in the lower right quadrant of the image. The port of Los Angeles is mainly to the right of the Dominquez Channel, and the Port of Long Beach to the left of the channel. Traveling up the channel from the port area, major oil refineries dominate the landscape (outlined in the rectangle and smaller image). This area refines approximately 10% of the nation's transportation fuel. Outside of those two areas, the watershed is comprised of other industries, residential, commercial, and some recreation areas. The Pacific Ocean can be seen in the lower left quadrant.

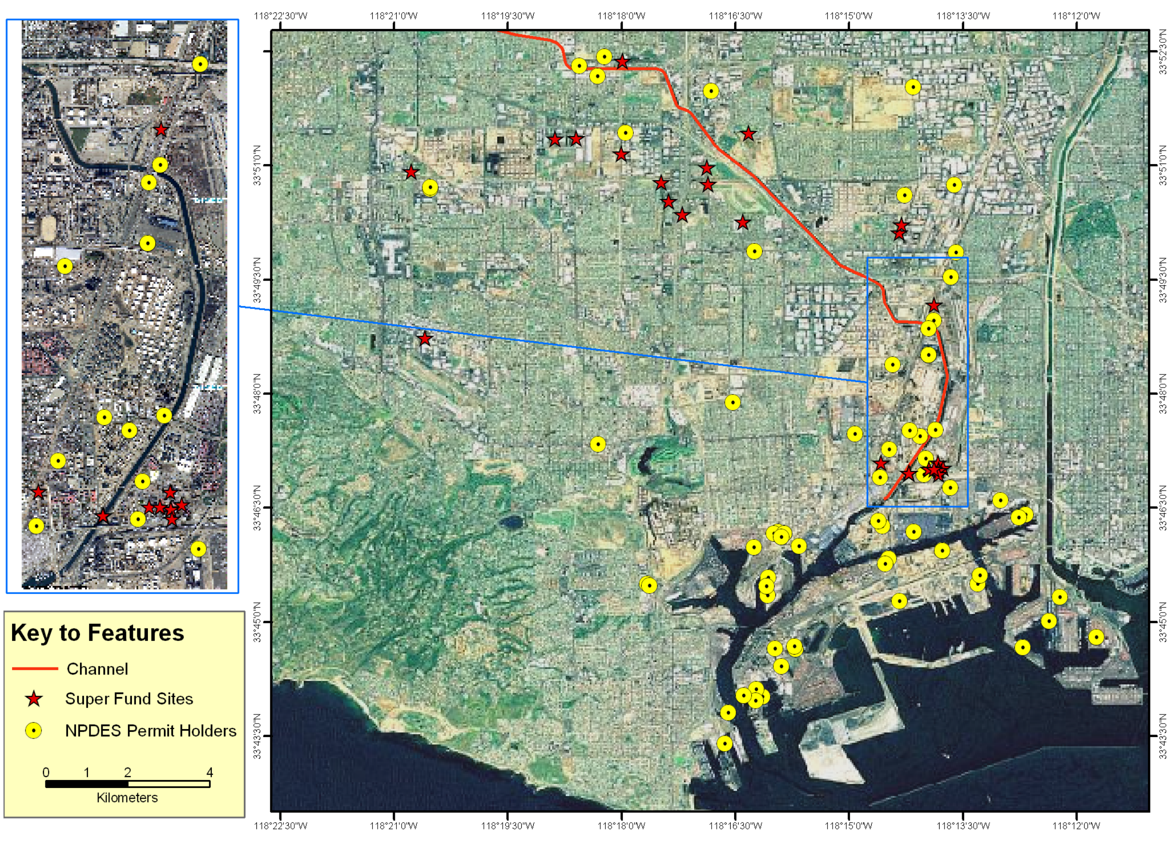

Figure 1: The Dominquez Channel.

2.5 The Dominquez Channel Watershed

The Dominquez Channel watershed is in the Los Angeles basin. It encompasses lands within the cities of Torrance, Hawthorne, Los Angeles, Rolling Hills, Rolling Hills Estates, Lomita, Lawndale, Manhattan Beach, El Segundo, Inglewood, Gardena, Carson, Ranchos Palos Verdes, Palos Verdes Estates, and Los Angeles County. The Dominguez watershed faces tremendous challenges including high-density development; conversion of remaining open space; flooding and development on floodplains; intense transportation pressures; increased demands for water and sewer services; reduction of wetland, riparian areas, and fish and wildlife habitat; and pollution of waterways. The EPA, through the California State Water Quality Control Board, has designated segments of the Dominguez Channel, Wilmington Drain, Torrance Lateral, Los Angeles and Long Beach Harbors and Machado Lake as "water quality impaired."

2.6 Reference System

Waste load allocations (WLAs) and load allocations (LAs) are expressed as the number of daily or weekly sample days that may exceed the single sample targets at a monitoring site. WLAs and LAs are expressed as allowable exceedance days because the bacterial density and frequency of single sample exceedances are the most relevant to public health protection. Allowable exceedance days are "appropriate measures" consistent with the definition in 40 CFR 130.2(i).

For each monitoring site, allowable exceedance days are set on an annual basis as well as for three other time periods. These three periods are (1) summer dry-weather (April 1 to October 31), (2) winter dry-weather (November 1 to March 31), and (3) wet-weather (defined as days of 0.1 inch of rain or more plus three days following the rain event). The contaminants listed in the Dominquez Channel are nutrients, trash, bacteria, and metals (Cu, Pr, Pb, Zn, TBT).

2.7 TMDL Process

Typically, the creation of a TMDL plan is based on information from one or more of the following sources:

1. Historical studies and local insight;
2. Sampling data;
3. Hydrology models;
4. Fate and transport models;
5. Stakeholder input.

The decision to use all or part of these sources is based on budgets, time, and regional decisions. Because many local agencies do not have adequate resources to conduct comprehensive studies on their respective watersheds, they often look to the stakeholders to provide data that will help in the determination of the TMDL. In the Dominquez Channel, the choice has been made to use all of these sources. Because the data collection and analysis is done in part with the decision-maker's resources and in part by a subset of the stakeholders, the final set of information will likely be different from what any single entity would collect.

The process described in Figure 2 will take place once the Dominquez Channel TMDL's decision-maker (the LARQWCB) receives all data. Implementation plans will be created and reviewed both before and after implementation. The review before implementation is the crucial time when stakeholders have some input and can voice their early opinions of the plan. Multi-attribute utility analysis can be used to evaluate the alternative plans faced by the decision maker, from the perspective of each of the different stakeholders. As discussed above, this will lend insight into the potential reaction of various stakeholders to the way the plan was developed and the type of plans proposed. Even though the decision-maker does not specify exactly how the responsible party will reduce discharges, the decision-maker does have an indirect say by setting a timetable and having the ability to evaluate plans by dischargers.

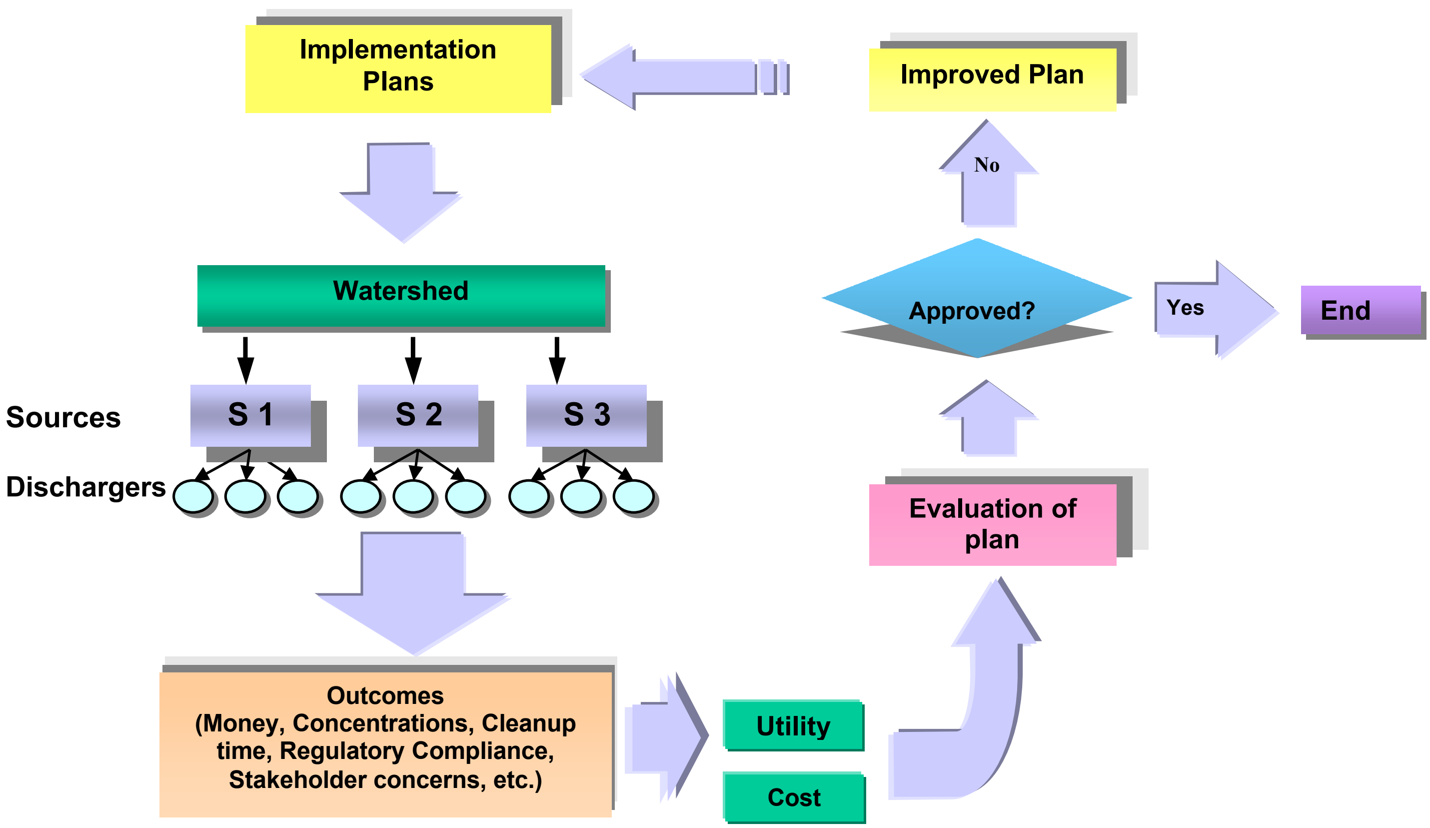

Figure 2. Illustration of TMDL process.

3: METHODOLOGY

Multi-attribute utility theory is a useful approach to aiding the decision-maker when faced with multiple and often conflicting objectives. In many situations, increasing the decision-maker's position relative to one objective will decrease his or her position relative to another objective. For example, choosing to improve water quality may cause an increase in clean-up cost. Thus, one's position regarding water quality has increased while one's position relative to cost has decreased. Multi-attribute utility theory allows one to structure decisions with multiple objectives, and formally conduct tradeoffs among competing objectives to achieve an overall best decision, or highest expected utility.

Models based on multi-attribute preference theory have been developed to help decision-makers logically and systematically address decision problems involving multiple attributes or criteria. These models adopt a set of reasonable preference assumptions that can be used to simplify the problem of comparing levels. With these assumptions, a decision-maker (or expert) indicates preferences for relatively simple decision situations to calibrate a preference model. The model is then used to establish how more complicated comparisons should be made to be consistent with the simpler comparisons and the preference assumptions.

There are a few basic types of questions asked when assessing a preference model. They involve a comparison of simple hypothetical alternatives labeled A and B. The questioning proceeds by varying one of the alternatives until the decision-maker is indifferent between (equally prefers) A and B. A set of model equations is then solved to compute model parameters that will reflect the decision-maker's preferences expressed by the comparisons of A and B. This will be further explained in Section 4 and in the Appendix.

This value judgment information is used for assessment, in a defensible manner, a multi-attribute ranking function. The function takes as input for any alternative the level assignments for each of the ranking criteria, and produces as output a single number suitable for comparing or ranking alternatives.

The main results of multi-attribute decision analysis theory cover *conditions* for which the ranking function can be expressed in a simple mathematical form, and meaningfully and consistently calibrated using preference information like that described above. The key aspect of such preference models is that they are derived formally on a mathematically sound basis.

The best problems to apply multi-attribute utility theory have the following characteristics:

1. A single decision-maker is undecided about the best way to solve a particular problem. There are viable options to choose from to address the problem, and the decision-maker must select among more than one possible path.

2. The problem can be structured in a way that clearly identifies the possible options, when the decision needs to be made, and if new information can be gained in future time steps that will influence future decisions. Decision trees are useful steps in structuring problems that have these characteristics.

3. If there are uncertainties in the outcomes of certain decisions, the modeler and decision-maker need to assign probabilities to the range of possible outcomes. There are numerous ways to approach this, including eliciting expert judgment, examining past empirical data, and using stochastic and dynamic programming.

4. The decision-maker assigns utility values to the consequences of each possible decision. These values will have levels of benefits and/or costs explicitly expressed with each possible

decision. These consequences will be ranked to reflect the decision-maker's preferences (e.g., $C^{/}$ is preferred to $C^{//}$, which is preferred to $C^{///}$). For consistency; $C^{/}$ must also be preferred to $C^{///}$.

$$C^{/} > C^{//} > C^{///}$$

Each consequence will have an associated utility value (e.g., $C_i^{/} \rightarrow u_i^{/}$ and $C_j^{//} \rightarrow u_j^{//}$). The assignment of utility values will also reflect the same preference:

$$\sum_{i=1}^{m} p_i^{/} u_i^{/} > \sum_{j=1}^{n} p_j^{//} u_j^{//}$$

Where $p_i^{/}$ equals the probability and $u^{/}_i$ equals the utility value for each possible consequence of a decision. The sum is called an expected utility, and maximizing the expected utility proves to be the optimal decision.

5. The final step is to select the levels(s) that maximizes the expected utility.

Multi-attribute utility theory has many rules to ensure that the methods are used correctly. While a comprehensive review of all of those rules falls outside the scope of this paper, a bibliography of detailed theoretical sources is provided in the reference section. Decision consequences are quantified in terms of attributes that measure the degree to which each of the multiple objectives (e.g. minimize cost, etc.) is addressed. A few of the desirable properties for developing attributes are as follows. Attributes should be:

1. *Comprehensive* to ensure that all important aspects are covered;

2. *Non-redundant* to avoid double counting;

3. *Operational* enough to be estimatable for alternative actions and to be meaningful to decision-makers for tradeoffs;

4. *Decomposable* to simplify both consequence and value modeling (e.g., satisfy helpful independence assumptions);

5. *Minimum number of attributes* to show meaningful differences between alternative actions;

6. *Appropriate scales*, either natural (such as time or dollars) or constructed (discrete levels, each associated with a well-defined description of conditions). Note: Arbitrary 0-10 scales are not well defined

In our approach, we structure the problem into the following characteristics:

1. Goal(s)— identify a concern a decision-maker wants to address;
2. Sub-goals/ Objectives—indicate the sub-concern to address as part of an overall concern;
3. Attribute(s)—define the measure used to quantify the degree to which any alternative addresses a sub-concern.

Goals are helpful in determining the level of achievement to strive toward. In our situation, the grand goal could be that the Dominquez Channel will meet the legal requirements for safe use in an acceptable timeframe. Goals may not be formally used in the modeling exercise, but they play an important role in determining objectives and attributes.

Objectives are more important in the analysis because they allow the problem to be broken down into measurable components. In the example TMDL case, one objective could be described as *characterization of contaminant sources.*

Attributes must be comprehensive and measurable. To be comprehensive, each individual level must clearly inform the decision-maker the extent to which its associated objective is achieved. To be measurable, one must be able to obtain a probability distribution over the possible levels of the attribute or assign a point value, and we must be able to assess the decision-maker's preferences for different levels of the attribute.

Multi-attribute utility/value function theory provides defensible assumptions and practical functional forms for quantifying values, including the following

$$U(x_1, x_{2,\ldots,} x_n) = \sum w_i v_i(x_i) \qquad \text{(additive form)}$$

$$U(x_1, x_2, \ldots, x_n) = [\prod (1 + K w_i v_i(x_i)) - 1]/K \qquad \text{(multiplicative form)}$$

where:

U is the overall summary (utility/value) number;
x_i are the levels for individual attributes;
v_i are individual attribute utility/value functions (scaled between 0 and 1);
w_i are scaling constants or weights reflecting the relative importance of the different attributes (tradeoffs) ranging from their worst to best levels (scaled between 0 and 1, with $\sum w_i = 1$ for the additive form);
K is a normalizing constant (computable by first solving for the variables $C_i = Kw_i$ and then letting $K = [\prod (1+ C_i)-1]$ for the multiplicative form

4: RESULTS

4.1 Stakeholders Objectives

We have conducted multiple interviews from 2002 to 2004, with representatives of each of the stakeholder groups. Those interviews gave us list of concerns and issues that are representative of their stakeholder groups. Each individual stakeholder did not participate due to time and resource constraint. However, all stakeholders were invited to participate in larger discussions of the issues and concerns. Any feedback from these less-frequent meetings has also been incorporated in the analysis. The feedback from the interviews has been structured into the following general categories:

- Transparency
- Establishing a well-characterized watershed.
- Schedule
- Cost
- Flexibility

Table 1 below shows the particular categories each stakeholder is concerned with.

Stakeholders	Transparency	Establishing a well-characterized watershed.	Schedule	Cost	Flexibility
Non-profit Organizations	X	X	X		
Industry		X	X	X	X
City Government			X		
Government Agencies		X	X		

Table 1. Dominquez Channel Stakeholder Groups and High-Level Objectives

Within these general objectives we have developed attributes based on the interview sessions. The objectives were drafted, shown to the stakeholder groups, and refined based on further input. These general descriptions were broken down further until we developed a list of attributes that explained the stakeholders' concerns and met our requirements listed above, i.e., both *comprehensive and measurable*. The following section (4.2) describes in detail, the eight attributes we have developed.

4.2 Attributes

The attributes below for both the characterization plan and the implementation plan are listed in order of preference: from greatest to least preferred.

CHARACTERIZATION PLAN

1) Contract Selection

This attribute expresses the concerns of the non-profit organizations who may feel left out of the assessment aspect of the watershed. The optimal situation for this stakeholder is to have a say on the selection of the group(s) that will be conducting the background investigations, preferring a group perceived to be neutral rather than firms that regularly depend on the industrial stakeholders for business. This attribute has the following two levels listed below:

- Non-profit organizations are included in contract team selection process for characterization

- Non-profit organizations are **NOT** included in contract team selection process for characterization

2) Characterization Plan Determination

Non-profit organizations also express concern over who determines the characterization plan. Similar to the contract assignment case, they often feel left out of the process. *Characterization plan determination* has the following three levels:

- Characterization plan is agreed upon by all stakeholders

- Characterization plan is agreed upon by NEPDES permit holders and LARQWCB

- Characterization plan is determined by NEPDES permit holders

The worst situation for this group would be to have the NEPDES industrial permit holders determine the types of background studies that will be conducted without input from the non-profit organizations and the regulatory body, LARQWCB.

3) Discharge Estimation.

Establishing a well-characterized watershed is the high-level objective that produced the lower-level objective of *estimating discharges*. A decision-maker has the right to revise the implementation plan after it has been put into effect, and a poorly characterized site could lead to conservative discharge limits. A discharge estimation attribute expresses the concerns of the, the "non-profit organizations," government agencies," and "industry" stakeholders' about the accuracy of the characterization with the following levels:

- Estimates all source discharges and requiring a small margin of safety

- Estimates most (meaning all major point and likely non point) source discharges requiring a small-medium margin of safety

- Estimates some (meaning all major point and few if any non point) source discharges and requiring a medium margin of safety

- Estimates few (meaning only few major point sources) source discharges and requiring a large margin of safety

The most preferred level is to identify all point and non point sources with high accuracy. The worse case is to only identify a small amount of the total contributions, meaning there is a high level of uncertainty requiring a high margin of safety.

IMPLEMENTATION PLAN

1) Timetable.

The list below describes timetable possibilities during which the implementation plan is executed.

- 0-.5 Years (Immediately)

- .5-2 Years

- 2-5 Years

- 5-7 Years

- Time Frame Unknown/ Calls for Extension

The "city government" stakeholders' timetable is based on guidelines for capital expenditures with higher levels requiring more time to pass through the agency. Once they hit a certain threshold, there may be a requirement to obtain the mayor and/or city council's approval. If this is necessary, the mayor's office will be asked to increase government spending. This timetable encompasses the range of options that cover both the "city government's" objective to increase public safety, which is apart of his overall environment plan with maintaining a business friendly environment. A priority for this stakeholder is to accelerate the cleanup of the Dominquez Channel. The worst levels listed for this group is an implementation plan in which a time frame is unknown, and extensions are requested leaving a level of uncertainty for both of the city government's goals of an improved environment with a defensible timetable for implementation.

"Industry" stakeholders' high-level objective of *flexibility* produced the lower level objective of *disruption of business activities*. The list of timetable levels above expresses the concern that regulations may unnecessarily disrupt their business activities. A long term, more than five years, timetable will minimize the level of disruption to business activities allowing industry to find reasonable technologies or solutions. A short-term, less than two years, timetable may disrupt business activities and this is least preferred to the industrial stakeholders.

The "government agencies" stakeholders are mainly concerned with having a gradual schedule, two years or more, for the implementation plan. A plan that is on short schedule - less than two years, is least preferred. The government agencies overall concerns are similar to those stated for "city government" above.

The "non-profit organizations" stakeholders expressed concerns of the implementation plan meeting regulatory requirements immediately without regard for cost or technology as their best level. The longer it takes for implementation, the less desirable it is for "non-profit organizations." In some instances the stakeholders cannot meet requirements or there were no new sources found during characterization and calls for more characterization is needed. This is illustrated in the "Time Frame Unknown/ Calls for Extension" level of the timetable attribute.

In summary, different stakeholders would assign different preference values to the timetable levels listed above.

2) Cost.

The attribute below expresses "industry's" concern over the cost of the implementation plan. These numbers are illustrative since negotiations have not been completed for this TMDL.

- Implementation Plan Requires No System Upgrades or Reduction of Output

- Implementation Plan Requires System Upgrades but No Reduction of Output.
  Cost < $250,000

- Implementation Plan Requires System Upgrades but No Reduction of Output.
  Cost > $250,000 but < $1,000,000

- Implementation Plan Requires System Upgrades but No Reduction of Output.
  Cost > $1,000,000 < $5,000,000

- Implementation Plan Requires System Upgrades and Reduction of Output.
  Cost > $5,000,000

"Industry's" main concern is the impact a TMDL may have on output in addition to the dollar amount for plant upgrades. The best outcome for this stakeholder would be to have no system upgrades or reduction of output. The worst situation would be to have an expensive system upgrade and a reduction of output. The scales show that they would be willing to make more expensive upgrades before they would be willing to reduce capacity. The dollar ranges reflect the increasing decision making authority within the industry that would be required to approve such an expenditure level.

3) Third-Party Monitoring.

“Non-profit organizations” stakeholders are concerned with this attribute since an implementation plan does not have much transparency. Listed below are the levels for this attribute

- Allows Third Party Monitoring of the Implementation Plan
- Does Not Allow Third Party Monitoring of the Implementation Plan

Third-Parting monitoring allows for outside organizations to feel confident that the regulations are being met. “Non-profit organizations” stakeholders want to ensure that the work is being done and in a timely manner, as drafted in implementation plan

4) Upgrades in Implementation Plan.

“Government agencies” stakeholders are the ones who are concerned with this attribute since having future upgrades requires them to go seek internal funding or a rate increase for a second time. We have the two following levels for this attribute:

- Implementation plan requires future upgrades
- Implementation plan does not require future upgrades

Upgrades in the system will require going back to the city government and requesting additional funding for the same reason. Once it goes back to elected officials, it becomes part of the political process and requires greater difficulty to be resolved. The preferred option is to have no addition upgrades after the initial implementation plan is executed.

5) Trading

Flexibility has been mentioned as a high-level objective by “industry”. The other corresponding lower-level objective is “*encourage discharge permit trading.”* The refineries expressed the idea of expanding the creative ways businesses can respond to meet the regulation while minimizing adverse impacts to the business community. The levels of trading are listed below:

- Implementation plan allows trading
- Implementation plan does not allow trading

The best attribute for “industry” would allow trading, potentially increasing the number of cost effective solutions. The worst situation for “industry” would be an implementation plan that does not allow trading within the watershed.

The following figures summarizes the goals and attributed for selecting the TMDL plan. The decision maker (LARWCB) is in yellow, the stakeholders are in blue, the higher-level objects are found in gray, and the attributes are in green.

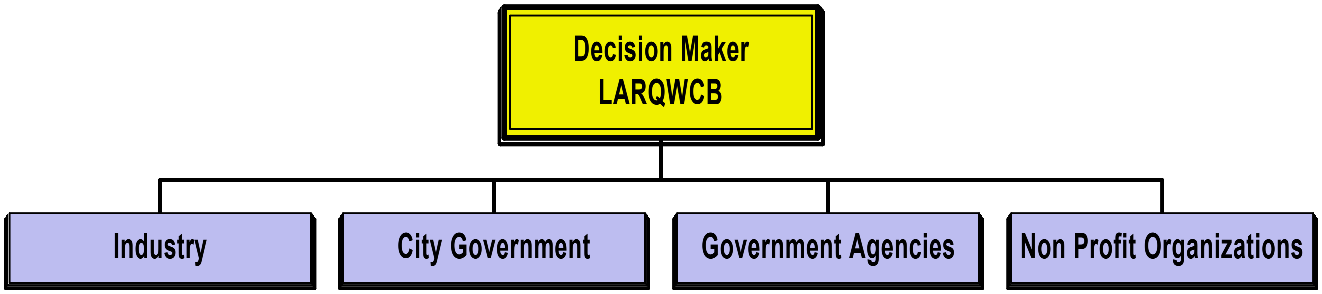

Fig. 3.1 A top down view of the decision maker and the four stakeholders.

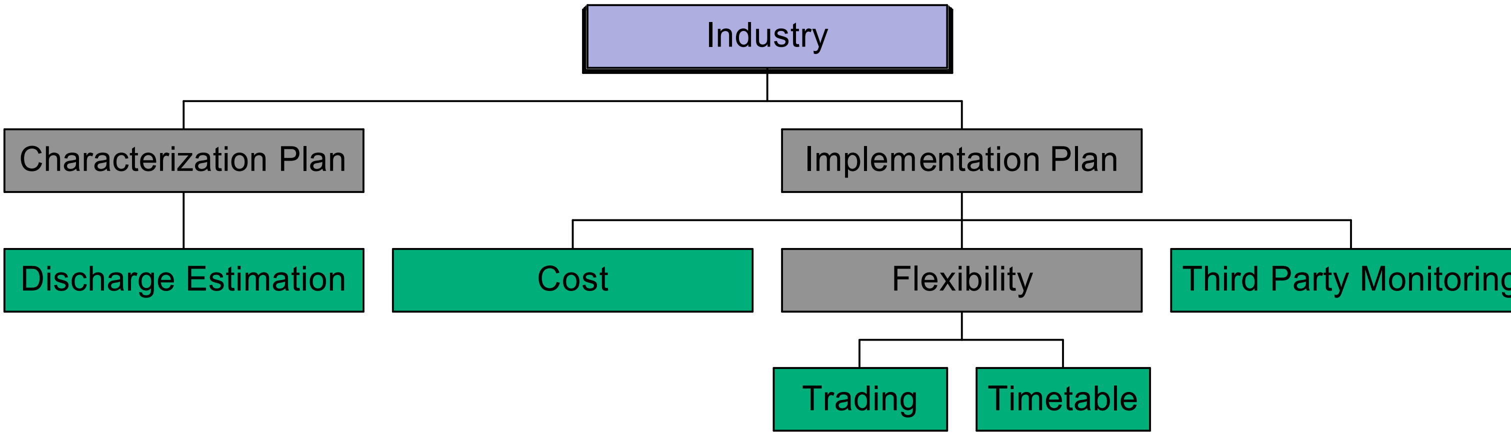

Fig. 3.2 Top-down view of "industry's" concerns

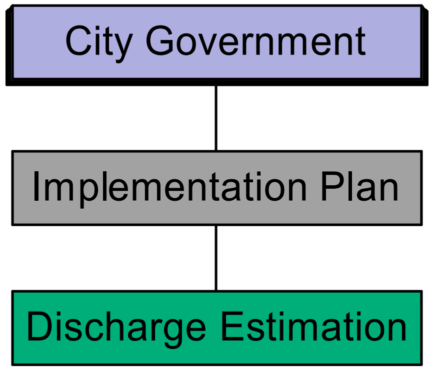

Fig. 3.3 Top down view of "city government's" concerns

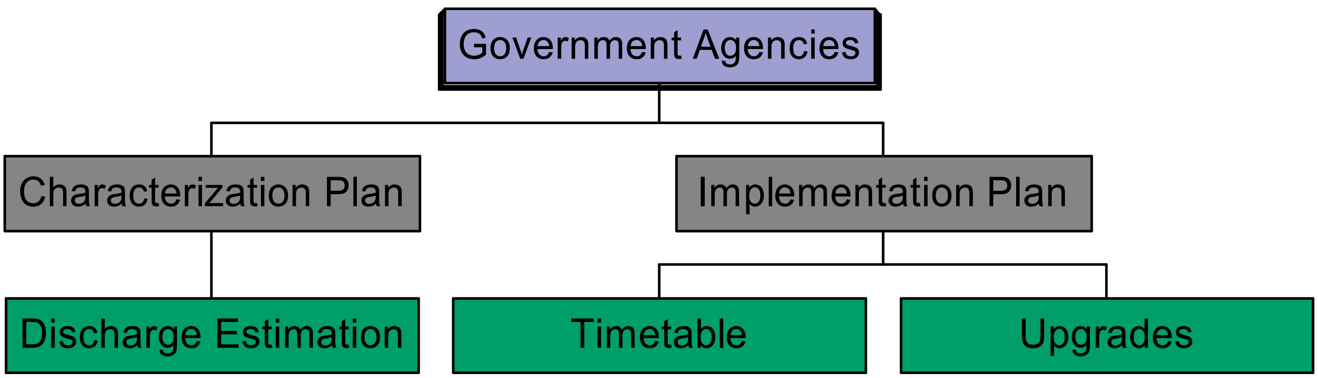

Fig. 3.4 Top-down view of "government agencies" concerns

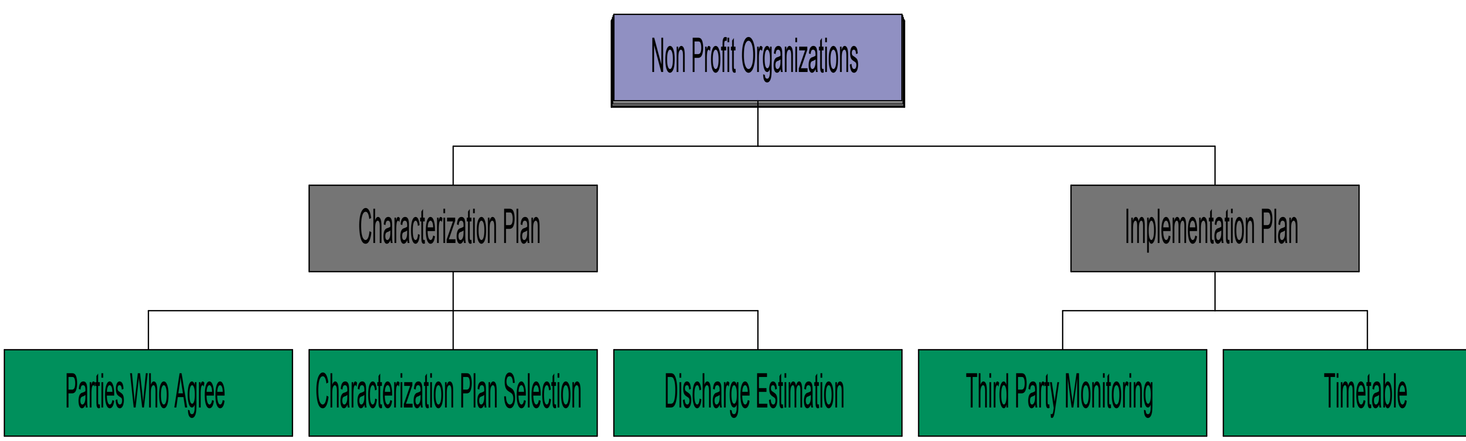

Fig. 3.5 Top-down view of "non -profit organizations" concerns

4.3 STAKEHOLDER ATTRUBITE MODEL IMPLEMENTATION

The SAM was implemented in the commercially available Logical Decisions For Windows® (LDW), a software designed to handle multi-attribute decision-making. It allows the user to structure Multi-measure utility functions (MUF) to assign values of importance to the decision makers overall objective. In the SAM model we used additive MUFs, since the attributes were all preferentially independent the ranges spanned by the attributes did not involve very extreme outcomes.

CALIBRATING SAM

Within any attribute listed above in section 4.2, we can assess the utility of corresponding levels. According to R.L. Keeney in *Siting Energy Facilities,* once we have chosen the attributes the assessment process can be broken into five parts:

1) Familiarization with the terminology and motivation for the assessment,
2) Verification of independence assumptions concerning preferences to specify the general value structure,
3) Assessment of the value tradeoffs among attributes to determine the scaling constants,
4) Assessment of the individual attribute utility functions, and
5) Checking for consistency and modification.

To implement SAM in LDW we used a lottery assessment in order to obtain utility values for each attribute level. To decide the utility of a level we asked the decision maker "Suppose that all other attributes besides one are at their most preferred level. Given alternative A of a lottery containing 90 percent probability that you will obtain the highest level objective versus 10 percent probability that you will obtain the least preferred level and alternative B being level 3 for certain, which alternative would you prefer?" The probabilities were varied until a setting was reached where the decision maker equally preferred alternative A to alternative B, say for example, 70 percent for the most preferred level. A utility of .7 was then assigned to level 3. This process was performed for each level of each attribute. A detailed explanation of lottery assessments can be found in the Appendix in "Question 1".

In order to find the weights for each corresponding sub-goal, we assessed tradeoffs. We asked the decision maker "how much of one sub-goal would he give up to go from the least to most preferred level of another." This is further explained in the Appendix in "Question 2".

Consistency checks are important since this model is based on the perspective of the decision maker. A consistency check was done in order to detect possible errors in the decision maker's overall utility function for the "Best TMDL Plan" goal. We must also make certain the decision maker's preferences are transitive.

CHOOSING THE BEST TMDL PLAN: AN EXAMPLE

Below is an example of two well-defined TMDL plans and how a decision maker could choose the best TMDL plan.

Attribute	**Plan 1**	**Plan 2**
Cost	Less than 250,000	Greater than 250,000 and less than 100,000,000
Trading	Allows trading	Does not allow trading
Discharge Estimation	Estimates some source discharges	Estimates all source discharges
Third Parting Monitoring	Allows third party monitoring	Does not allow third party monitoring
Timetable	5-7 years	2-5 years
Upgrades	Requires System Upgrades	Does not require System Upgrades
Characterization Plan Selection	Non-profit organizations are **not** included	Non-profit organizations are included
Parties Who agree Upon Plan	NEPDES and LARQWCB	NEPDES

Table 2. Illustration of two different TMDL plans.

The illustrative alternative plan information in Table 2 was analyzed using LDW. We can obtain results like the following graph below comparing the overall utilities for the two TMDL plans.

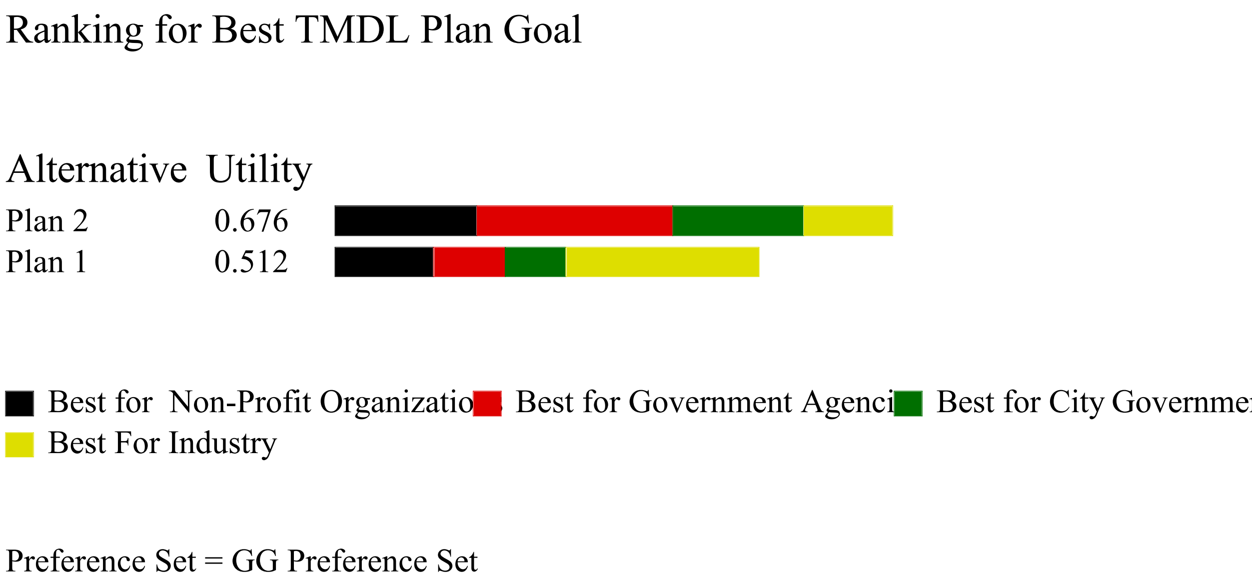

Fig. 4: Ranking for the Best TMDL Plan.

Figure 4 is a “Stacked bar ranking” of results created in LDW. As shown, the “non-profit,” “city government,” and “government agencies” stakeholders prefer Plan 2. Industrial stakeholders, on the other hand, preferred Plan 1 to Plan 2 because it had higher utility values for the “trading,” “timetable,” and “cost” attributes.

5: DISCUSSION

The implementation schedule for the Dominquez Channel watershed has been delayed to allow for more studies to be completed by the stakeholder groups. The stakeholder attribute model we have built will allow the decision-maker, the California Regional Quality Water Board, Los Angeles Region, to formally assess various stakeholders’ attitudes and concerns about the various implementation plans from which they must ultimately select. It was shown in the results section that SAM is capable predicting the best TMDL plan for stakeholders based on their respective preferences.

6: CONCLUSIONS

The TMDL process has required federal, state, and local agencies and stakeholder groups to create plans to reduce discharges into impaired waterways, with minimal resources and data to make the scientifically proven “best choice.” The development of the SAM model was explicitly selected with this in mind. The SAM model does take time and resources to build; however, the cost is within reach of many state and local agencies. The model’s advantages are (1) cost relative to other modeling approaches, (2) usefulness given source uncertainty, and (3) increased fairness to stakeholders. By formally incorporating stakeholder values, the decision-maker can select an implementation plan that systematically and explicitly addresses the values of each stakeholder group. This method does not claim to make each group come out with the overall best solution; rather it provides a tool that allows the decision-maker the ability to weigh each stakeholder group's goals and determine the best tradeoffs, given quantitative information on each group's value system.

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Calibrating A Utility Model

There are a few basic types of question asked of a decision maker (or study team) in calibrating a preference or utility model. Each involves a comparison of simple hypothetical alternatives labeled A and B. The questioning proceeds by varying one of the alternatives until the decision maker is indifferent between (equally prefers) A and B. A set of model equations is then solved to compute model parameters that will reflect the decision maker's preferences expressed by the comparisons of A and B.

Question Type 1: Preferences for different levels of a particular attribute (calibrating individual attribute utility functions). In this type of question, only one attribute is varied; all other attributes are fixed for both A and B (i.e., A and B are identical on all attributes except one). The following kind of question can be asked:

Given the following "sure consequence" for A and the following "gamble" for B, for what probability *p* of winning the gamble is A equally preferred to B?

Alternative A		Alternative B
		p chance of most preferred level
Intermediate level	versus	
		(1-*p*) chance of least preferred

In this question, the probability *p* is varied until A and B are equally preferred. For *p* very close to 1, B will be preferred to A. For *p* very close to 0, A is preferred to B. We gradually vary *p* away from 0 and 1 until A is equally preferred to B. This *p* determines the utility of the particular intermediate level relative to least and most preferred levels for the attribute. Questions of this type are asked to assess utilities for all the levels of all the attributes.

The minimum number of assessments for an attribute with m discrete levels is (m-2) since levels 1 and m of the attribute have utilities of 0 and 1 respectively by the scaling convention. However, in addition to this minimum number, extra "consistency checks" are asked to verify that the assessments have been done in a logical manner and that the definitions of the attribute levels are reasonably clear and well-understood.

The calibration procedure illustrates that we do not simply assume that because an attribute has 5 levels, for example, that the value of level 3 is midway between that of levels 1 and 5. The values assigned to the attribute levels are directly related to the definitions of the attributes, and not the index of the level.

Question Type 2: Tradeoffs between two attributes (calibrating the scaling/weights constants). In this type of question, two attributes are varied; all other attributes are fixed for both A and B (i.e., A and B are identical on all attributes except two). The following kind of question can be asked:

Given the following pairs of consequences for A and B respectively, which alternative is preferred?

Alternative A			Alternative B	
Attribute One,	Attribute Two		Attribute One,	Attribute Two
Best level	Worst level	versus	Worst level	Best level

Notice that this type of question addresses the issue of tradeoffs (relative importance) directly. In Alternative B, Attribute One is at its least favorable level while Attribute Two is at its most favorable. In Alternative A, things are reversed. If a person prefers A to B, the implication is a willingness to move from the best level to the worst level for Attribute Two in order to improve from the worst level to the best level for Attribute One (i.e., the tradeoff is being expressed).

As with Question Type 1, we want to "home in" on a situation where A and B are equally preferred, but where there is a tradeoff occurring. The following kind of table illustrates how such homing in occurs.

Tradeoff table example:
Attribute One (5 point scale) versus Attribute Two (4 point scale)

Alternative A		Alternative B		Preferred
Attribute One,	Attribute Two	Attribute One,	Attribute Two	(A, B or =)?
5	1	1	1	A
5	1	1	2	A
5	1	1	3	A
5	1	1	4	A
4	1	1	4	A
3	1	1	4	=
2	1	1	4	B
1	1	1	4	B

Each line in the table has a version of Alternative A is pitted against a version of Alternative B. All the versions of Alternative A have in common that Attribute Two is set at its least desirable level. All the versions of Alternative B have in common that Attribute One is set at its least desirable level. In the top line, it is obvious that A is preferred to B. In the bottom line it is obvious that B is preferred to A. At each line in going from top to bottom, B is getting better or A is getting worse, so at some point there will be a cross-over and B will be preferred to A. At this cross-over point, A will be "equally preferred" to B. (If needed, one can linearly interpolate with attribute levels, e.g., level 1.5. The interpretation is that such an alternative has some of the additional features of level 2 but not all, and therefore is between levels 1 and 2.)

REFERENCES/BIBLIOGRAPHY

AMEC Earth & Environmental. 2004. *Consolidated Slip Restoration Project Draft Alternative Summary Report*. Prepared for Los Angeles Regional Water Quality Control Board and the Port of Los Angeles. April 2004.

Dominguez Watershed Advisory Committee. 2003. *Draft Dominguez Watershed Management Master Plan*. Prepared by MEC Analytical Systems. April 2003.

Keeney, R.L and H. Raiffa. 1993. *Decisions With Multiple Objectives.* Cambridge University Press, New York, 1993. (First published in 1976 by Wiley, New York)

Keeney, R.L. 1994. "Using Values in Operations Research," Operations Research 42, pp. 792-813.

Keeney, R.L. 1980. *Siting Energy Facilities.* Academic Press, New York, 1980.

Los Angeles Regional Water Quality Control Board. 1994. Water Quality Control Plan, Los Angeles Region.

Los Angeles Regional Water Quality Control Board. 1996. 1996 California Water Quality Assessment 305(b) Report: Supporting Documentation for Los Angeles Region.

Los Angeles Regional Water Quality Control Board. 1998. Proposed 1998 list of impaired surface waters (the 303(d) List). March 24, 1998.

Los Angeles Regional Water Quality Control Board. 2001. *Proposed amendment of the Water Quality Control Plan—Los Angeles region to revise bacteria objectives for waters designated for contact recreation*. July 31, 2001.

Los Angeles Regional Water Quality Control Board. 2002. *Total Maximum Daily Load to Reduce Bacterial Densities at Santa Monica Bay Beaches During Dry Weather*. January 14, 2002. Available at: http://www.swrcb.ca.gov/rwqcb4/html/meetings/tmdl/santa_monica/02_0114_tmdl%20Dry%20Weather%20Only_web.pdf.

Los Angeles Regional Water Quality Control Board. 2003. 2002 CWA Section 303(d) List of Water Quality Impaired Segments. July 2003. Available at: http://www.swrcb.ca.gov/tmdl/303d_lists.html.

MEC Analytical Systems, Inc. 2003. *Dominguez Channel Bacteria TMDL Study 2003*. Prepared for the Los Angeles Regional Water Quality Board and Southern California Coastal Water Research Project. October 2003.

State Water Resources Control Board (SWRCB). 2003. Clean Water Act Section 303(d) List of water quality limited segments. February 4, 2003.

State Water Resources Control Board (SWRCB). 2004. Porter-Cologne Water Quality Control Act, with Additions and Amendments Effective January 1, 2004. California Water Code, Division 7, Water Quality, 124 pp. Available at: http://www.swrcb.ca.gov/water_laws/docs/portercologne.pdf.

U.S. District Court, Northern District of California. 1999. Heal the Bay Inc., et al. v. Browner, et al. Case No. 98-4825 SBA. March 22, 1999.

U.S. Environmental Protection Agency. 1986. *Ambient Water Quality Criteria for Bacteria—1986*. EPA 440/5-84-002, Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1991. Guidance for water quality-based decisions: the TMDL process. EPA 440/4-91-001. Office of Water Regulations and Standards, Washington, D.C.

U.S. Environmental Protection Agency. 2001. Protocol for developing pathogen TMDLs. EPA 841-R-00-002. Office of Water (403F), United States Environmental Protection Agency, Washington, D.C.